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PLANTATION RUBBER IN HAWAII

BY

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INTRODUCTION.

The rubber industry in Hawaii finds itself under a disadvantage as regards the cost of labor as compared with rubber plantations in other countries. The price of labor may be reduced in Hawaii, while wages in most of the rubber plantation countries are increasing. How far this movement will go no one can say. It is safe to predict, however, that the price of free labor in Hawaii will not for many years reach the level of the wages paid to the contract labor of the far East. To be sure, the cost of supervision, and general "overhead charges" are rather less in Hawaii. There still remains, however, a consirerable balance in favor of the Eastern plantations.

To minimize this difference will require constant effort toward better methods and closer economies. Fortunately, the rubber industry is in its infancy the world over, and holds possibilities of important discoveries in methods of tapping, and even, possibly, of cultivation. In Bulletins Nos. 16 and 19, and Press Bulletin No. 13, of this Station, are given the results of various experiments in tapping, and general observations on the industry in Hawaii up to the time of their publication. The aim of this Bulletin is to give a summary of the observations made since their publication.

PLANTING.

The plantations were naturally all started with seedlings. Cuttings will probably henceforth be the best method of propagation. The cuttings planted in 1907 have grown as well as seedlings under the same conditions, and yielded as well. Planting with cuttings permits selection from the best yielding trees. One acre was planted in 1911 in this way. These will be tap-

pable by the end of the next tapping season, when they will be two years old. It will then be possible to determine whether or not they partake of the high yielding properties of the parents. If they do, this will prove unquestionably the best method of extending the plantations, as the well known variation in yielding capacity of different trees will in this way be largely eliminated, and a plantation developed on which all the trees are good yielders.

While 100 trees per acre would appear to be approximately the proper number for a permanent stand, there are distinct advantages in planting closely and subsequently thinning out by removing the poor growers and poor yielders. Among these advantages are:

A. The ground is more quickly covered by foliage, making weeding expense less, and reducing erosion.

B. The trees protect each other to a greater extent from damage by heavy winds.

C. Close planting allows thinning out by selection. This is, perhaps, the chief advantage. Thinning out can be done as the trees begin to crowd each other, by first removing the poorest growers, then, the trees which have been found to yield poorly. As the trees are not true to seed as regards yielding properties, this would seem to be the only effective method of selecting the best individuals, so long as planting is done with seedlings. In the case of selected cuttings, naturally, this is of less importance.

D. With the trees closely planted better results are obtained from early tappings. Until they begin to crowd each other to such an extent as to affect the flow of latex, it is obvious that more rubber will be obtained from 400 trees per acre than from 100. This, of course, holds equally true in the case of cuttings. So long as the yield per tree is not affected, the more trees per acre the more rubber per acre. This principle appears to be gaining ground in the eastern plantations, and less is heard than formerly of the discussion as to close vs. wide planting[1], although opinions as to the proper distance for the permanent stand have not greatly altered.

The disadvantages urged against close planting are:

A. The trees are apt to be left too long before thinning, so that a permanent set-back is given them. This objection is not necessary to the system, but depends on the planter.

B. Thinning out by selection leaves the trees more unevenly spaced than if originally planted 20x20. This irregularity will permanently increase the cost of tapping per acre.

The amount of this increase will depend on the method of working. For instance, if the trees are evenly spaced, 20x20, there are 108 trees per acre, equivalent to 9 rows of 12 trees

1. See Tropical Agriculturist, Jan. 1913.

shifting at the ends of the rows ,making a total distance traveled of 2160 plus 180, or 2340 feet, in tapping one acre. If the acre contains the same number of trees, thinned by selection from planting 10 by 10, there will be 18 rows containing an irregular number of trees but averaging 6 trees per row. In tapping by rows, the man must travel 240 feet for each of the 18 rows, and the same distance as before in shifting, making a total of 4320 plus 180, or 4500 feet, in tapping the acre. The difference is 2160 feet additional distance traveled in tapping the irregular trees—nearly twice as far, and, roughly speaking, one mile for each two and one quarter acres tapped. In tapping a thousand trees, he will cover 9 acres, traveling an additional distance of 4 miles.

This difference can be materially reduced by tapping two rows at a time in the second instance instead of one. In this way, the additional distance traveled for each two lines will be reduced to about five feet for each tree in the second line. If this second line contains only two trees, for instance, it will be necessary to travel only ten feet farther in tapping these two lines than in tapping one. If this were the average content of second lines, then, the additional distance traveled for the acre would be only 90 feet or 810 feet for each thousand trees. The maximum possible content for the second lines is six trees, hence the miximum possible difference in travel will be 30 feet for each two lines, 270 feet per acre and 2430 feet per thousand trees—less than 1/8 that caused by the single row system. This applies of couse, only to cases where the trees are irregularly placed, or where the distance between each two rows is less than the average distance between each two trees in the rows. It therefore does not apply to either the 10 by 10 planting before thinning, or 20 by 20 planting.

It does, however, reduce the necessary additional cost of tapping per acre caused by irregular spacing, to a point where, as compared with the advantages of close planting pointed out above, it is negligible.

C. Cost of thinning out. The cost of cutting down and removing trees of the size these will be, if removed at the proper time, is more than offset by the gain made through the selection of the best 1/4 of the trees.

D. The danger of fostering diseases and pests by the dead stumps left in the field in thinning out. This is, so far, a theoretical objection. In some of the Eastern Hevea plantations, where the policy has been pursued for several years, no evidence has been discovered of injury from this source. (See summary of paper by Mr. C. E. S. Baxendale in the Tropical Agriculturist for Jan. 1913.) It can be guarded against, if considered necessary, at some additional expense, by removing each. Tapping these, one row at a time, the tapper walks 240 feet for each of nine rows, and 20 times 9, or 180 feet in

the stumps, which at this age are not large. So far, in the Nahiku district, the stumps have been left in the ground.

On the whole, the practise of planting the trees ten by ten and thinning out by selection to the desired number per acre is justified by results. Its chief advantages are the increased yield per acre during the first tappings, and the opportunity it gives of thinning out the poorer trees, leaving only the best. Most of the fields have been thinned somewhat, but comparatively few acres have been reduced to 108 trees per acre. This will probably not be completed before the trees are 8 or 9 years old.

CULTIVATION.

The question of cultivation is one of providing for the proper nourishment. The three main factors are weeding, fertilizing, and aeration. According to present theories there are two classes of noxious weeds; those which are positively injurious through their toxic effects, and those whose injuriousness is confined to the removal of necessary nourishment from the soil. Some plants may cause injury from both these causes. Besides these there are the beneficial weeds, as the legumes. It is also conceded that these beneficial plants may be grown under such conditions as to become injurious; as with legumes, while adding nitrogen, they might, especially the shrubby sorts, under certain conditions, remove too much potash or phosphoric acid.

Most of the work in Nahiku has been directed toward extermination of injurious weeds. Some attempts have been made to replace the injurious weeds with legumes, but for this to be done to the best advantage, it should be done at the time of planting the trees, and soon after clearing, before other growth has obtained a footing. Cutting the grass and mulching is recommended by some authorities for orchards in hilly country (Ohio Exp. Sta. Bulletin No. 240). This was done at Nahiku for about four years. A cheaper and apparently as effective method was found in the arsenite of soda spray, which is the subject of another bulletin of this Station. (Press Bulletin No. 30.) One purpose of the mulch, the conservation of moisture, is not needed in Nahiku. The spray is in general use on all the plantations. In Nahiku, the abundant and frequent rains, with numerous gulches, in which water can be found convenient at all seasons of the year, make it especially adapted. It allows the air to get to the soil rather better than the cutting and mulching, as the dried grass stems are left standing for some weeks after application and when they do fall over it is a gradual bending down, and the base of the stems still hold the mulch slightly off the soil until decay is somewhat advanced.

Arsenite of soda should not be allowed to touch the foliage of any trees or the stems of Ceara trees under two years of age, or of Hevea trees at all. In the case of Ceara trees over

two years of age, the tough outer bark furnishes protection from injury. If allowed to touch them where this bark has been recently removed for tapping, however, all the inner bark is burnt off to the wood. Properly handled, it is the cheapest effective method of weeding yet found. Horse cultivation, where it is possible, on the more level lands gives good results, but this can not be employed on all the lands without excessive loss from erosion. Hoeing the entire surface, the common practice in the far east, is impracticable for two reasons, the loss by erosion, and the enormous expense.

INTERPLANTING.

A great deal has been written and considerable work done on the subject of keeping down obnoxious weeds fostering the growth of those less obnoxious or of beneficial plants. Passion vines, peanuts, Crotalaria and other legumes, have been used. With all, the main idea was the choking or shading out of undesirable growth. So far, we have not found this profitable. It is possible that this was because our experiments were made after the Hilo grass and other troublesome weeds had become established. It was then necessary, in order to get the beneficial plants established, to keep hoeing out the undesired growth. It was found more expensive to establish and maintain the legumes than to keep the grasses down with the spray. It is possible that the advantages gained through the addition of nitrogen by the legumes might offset this additional cost, but this is doubtful.

A better practice, where horse cultivation can be employed, is the planting of intercrops, which are valuable for themselves, aside from weed checking. The additional cost of the cultivation can be more than recovered from field corn, Irish potatoes, broom corn, and probably from others. Sweet potatoes have been found to grow well and yield heavily on the lower lands. If a profitable local use can be found for these, they should be a good crop for the purpose, as the vines furnish a complete cover to the soil for several months, and, after harvesting, supply a good quantity of manure. Field corn does rather better on the high lands. Broom corn grows excellently, and yielded three crops from one planting. The bulkiness of the crop in comparison with its value, however, makes it undesirable where transportation facilities are at all difficult. In general, it may be said that any crop that can be grown profitably in the district can be used as an intercrop. Naturally, other things being equal, the crop will be selected which will take the least nourishment from the trees. In soils rich in humus, as most of the Nahiku soils are, it would seem that no serious impoverishment of the soil should result from the raising of two or even three, crops of any suitable sort.

FERTILIZING.

Much work remains to be done on this subject. Some soil analyses made by Mr. Kelley of this station, showed a large amount of humus, and generally speaking a sufficient amount of the chief food essentials. He points out, however, that the occurrence of the iron in the ferrous state indicates the need of aeration. An experiment was made in 1909 to determine if possible the effect of ammonium sulfate, superphosphate and potassium sulfate, alone, and in combination. Results in growth as compared with the check trees that were given the same cultivation without fertilizer, were not marked, and, while this experiment is not considered conclusive, it would seem to indicate that, considering the additional cost of the fertilizer, possibly, for some time, at least, aeration and cultivation without the addition of fertilizers should give as satisfactory results.

An important subject of investigation, and one which has not as yet been undertaken on a large scale, is the effect of fertilizing on the yield of latex. Some experiments were made by this station in 1909, the results of which are reported in Bulletin No. 19. It is hoped that during the present year, these may be supplemented by a carefully planned and executed experiment on a field scale, on a large enough number of trees to make individual variation in yielding properties negligible, and continued from the beginning of the growing season to the end of the tapping season.

AERATION.

The availability of plant foods in the soil depends on a sufficient supply of oxygen. Most of the soils on the upper lands in the Nahiku Rubber district are rather finely divided, and either saturated with moisture to the exclusion of air or reduced by erosion and packing to impenetrability to either air or moisture. In some places ditches have helped to promote circulation, but something further is needed to provide thorough aeration. Horse cultivation gave quick and noticeable results where it could be employed. This, however, stirs up the top soil for only a few inches, and much of the benefit is counteracted by the loss of the best top soil from erosion.

In April of this year an experiment was made with dynamite in the hope that this, in connection with weed eradication by arsenite of soda, might furnish a fairly complete method of cultivation in this district, where the combination of steep slopes and heavy rains and finely divided soil, covered with trees having large surface roots, makes other methods of cultivation difficult and expensive. It is too early yet to note the effect on the trees, but the experience of others where dynamite has been used in orchards, leaves the question only one of the

amount of benefit received. As the benefits of this sort of cultivation have been found to last for 10 to 20 years on the mainland, the cost of fifteen to twenty dollars per acre, would seem to be small as compared with the benefit to be expected. In damp soil the dynamite shows a tendency to make a balloon-shaped hole, and the shattering effects extends over a smaller area. The holes formed, however, are as a rule filled with well-loosened soil, providing good opportunity for aeration.

TAPPING.

The tapping difficulties peculiar to the Ceara tree are due to the character of the outer bark and the thinness of the inner bark, containing the latex cells. For any system of tapping by excision the thinness of the inner bark offers the chief objection. It is impossible to make a channel that will extract the maximum amount of latex and conduct it to the cup without frequently reaching the cambium. At the same time, the nature of the outer bark offers serious obstances to tapping by incision. If this bark is not removed before incision, much of the latex is lost between the outer and inner barks. The following mothods have been tried on the trees at Nahiku:

1. Paring and collecting in cups at the base of the tree. Vertical cuts, single V, multiple V, half herring bone and full herring bone were all employed. The tendency to either injure the cambium or fail to get the full yield of latex applies equally, which-ever system of cuts is employed.

2. Paring and pricking, and collecting in cups. To avoid injury to the cambium, the excisions were made more shallow and followed by pricking to get the latex near the cambium. This gave better results than 1, but it was found difficult to conduct the latex in the shallow channels.

3. Removal of the entire outer bark and pricking vertically with a wheel pricker, collecting in cups at the base of the tree. This gave good yields immediately after the removal of the bark, but the injury caused by bark removal and the rapid formation of a new outer bark, preventing a long series of tappings, after one stripping with the cost of repeated bark removal, are serious objections.

4. Removal of the outer bark in horizontal sections, painting with acetic acid to coagulate the latex, and pricking or jabbing. This method is advocated by Wicherly. The cost of applying acetic acid and collecting the rubber coagulated on the trees was too high.

5. No. 4 was modified and simplified by allowing the latex to flow to the ground and coagulate there. This worked very well for the first horizontal section and the first stripping, but on higher sections too much latex was coagulated on the tree, and the stripping of renewed bark was expensive.

6. Removal of the outer bark on a one foot horizontal section, followed by a vertical incision with a knife-blade the full length of the section, allowing the latex to coagulate on the ground. This gave good results until the first section had been exhausted, but could not be continued higher up on the tree, and subsequent removal of the renewed outer bark at the base of the tree was very expensive.

It became evident, during the progress of these experiments, (a) that a good grade or rubber could be obtained more cheaply by allowing the latex to coagulate on the ground and washing carefully, than by using cups and spouts; (b) that a good yield could be obtained from a knife-blade incision after removal of the outer bark; (c) that the outer bark should be removed in sections and not all at one time. Therefore, a knife was needed which would remove this outer bark on the section desired at one operation. It is the renewed bark which gives the chief trouble. A knife was finally made which would remove the outer bark in strips of any desired width, leaving the inner bark exposed for incision. In August, 1912, tapping was commenced by the following method: The outer bark is removed in a vertical strip, ¾-inch wide from the ground to a height of about 6 feet. The following day the inner bark is jabbed with a thin blade 1-inch wide, as light in weight as consistent with the necessary rigidity. The incisions are made diagonally sloping upward from the left, at an angle of about 45 degrees and about 4-inches apart. The latex flows to the lower end of each incision, and then down the smooth inner bark to the next incision below, follows along to the lower end of this, then down to the next, and so on, till it reaches the base of the tree in a single stream. This is repeated on each of the next two days, making three tappings by incision, in three days. On the day following the last tapping, the coagulated rubber is collected and taken to the washing machine.

The process is thus divided into three operations; removing the outer bark, (excision), jabbing the inner bark (incision), and collecting. The best men are selected for the removal of the outer bark. After a few weeks of experience this operation was performed at the rate of 1200 trees per day's work. The jabbing can be done at about the same rate. Collecting is at the rate of about 12 to 15 lbs. per day's work.

During the eight months, August, 1912 to April, 1913, on one field of trees averaging 6 years old, it took 710 days' work to tap and collect 2193 lbs. washed rubber. During the same time these trees produced 440 lbs. of rubber that coagulated on the trees, and was collected as scrap. Thus, roughly speaking, the yield may be estimated at three pounds per day's work, and 20% of the latex coagulates on the tree.

As mentioned above, it is difficult to tap the Ceara tree by excision, without too frequently injuring the cambium. At the

same time, the character of the outer bark makes its removal desirable before incision. In the method just outlined, the aim is to remove only the outer bark by excision. There is no effort to obtain latex at this operation. It does happen, however, that the knife sometimes enters the inner bark. The effect of this instead of causing injury, is simply to start a flow of latex. There is little danger of injuring the cambium in removing the bark. The chief danger lies in the careless use of the jabbers. A quick, light incision causes no apparent injury. If the cut is made with too much force, however, or the blade, instead of being directly withdrawn, is allowed to turn or scrape in the cut, a wound is made which causes a permanent lump in the wood. The chances of this are greater in the case of small trees or trees whose bark is thin. It is possible that a wheel pricker can be evolved which will do away with this objection.

The method of collecting directly from the soil without cups has been practised widely in other Ceara growing countries. It is hoped, however, that a container will eventually be found which can be used in such a way as to facilitate collecting. A circular trough of cement and sand is now under trial at the Sub-Station.

As a receptacle it is quite satisfactory, when properly made, and allows tapping on the lowest portion of the trunk, which is essential to the best yield. Its economy will depend on the length of time the trough will last without repairs. Some that have been on the trees for four months are still in good condition.

The proportion of rubber that remains on the trees to be collected in the form of scrap varies according to the weather. During dry weather, as much as 30% has been collected as scrap, while in ordinary weather, with daily rains, the amount is much smaller, and during November of last year, it was so small as to be not worth collecting. While the so-called "scrap rubber" collected in this way, by washing, can be made as valuable as that collected at the base of the trees, it costs more to collect, and consequently, the greater the amount of scrap, the more expensive the tapping is as a whole.

During August and September the tapping was rather light, but through October, November and December of 1912, and January, February, March and nearly through April of 1913 the trees were tapped on an average of four times in seven days, or 16 times a month. As previously ascertained, the yield is less during hot dry weather, and the amount of scrap is greater. In cloudy and rainy weather, such as occurs usually in October, November and December, and in February and March, and often in April, the tapping can be carried on well into the afternoon, while in dry weather it must be done in the morning. It was found good practice to plan the work so as to have the jabbing, from which the latex is mostly obtained, done

in the morning, and to use the labor for collecting and other work during the remainder of the day. The conclusion as to the proper season for tapping is that good yields can be obtained from September to April, in ordinary seasons.

CURING.

A good rubber is one free from mechanical impurities, of high tensile strength, high elasticity, and low resin content. The standard with which all rubber is compared, is Upriver Fine Para. Until within the last two years, this rubber received the highest prices in the market. Of late, however, the sorts generally known to the trade as "Ceylon Plantation", by which is meant all the Far Eastern Plantation Para (Hevea) rubber of the best quality, have been quoted higher than Fine Para. Ceylon Plantation rubber contains practically no mechanical impurities, while Upriver Fine may contain as high as 15% or even 20%. Generally, however, the purchaser of Para is protected against a loss of more than a certain per cent. Ceara, or Manihot, rubber contains more resin than Para, and is generally of lower tensile strength.

With the method of collecting described above, it is naturally more difficult to free the rubber from dirt than if it were collected in cups and kept clean throughout its manipulation. This is done by washing with corrugated rollers, which leave it in the form of coarse crepe.

Resin content is generally understood to be affected by the variety and age of the tree, and to have very little connection with the method of curing, though there is some slight indication that it may be affected by the character of the weather during which the trees are tapped. If this is true, it would naturally follow that it would be affected in the same way by the general climate in which the trees are grown. The data on this, however, are not sufficient at this time to warrant a definite conclusion. The indications are that hot, dry weather may increase the resin content. The establishment of this theory is a matter for further investigation.

Tensile strength and elasticity are affected by the method of curing. Our experience indicates that the method of drying has more to do with this than the method of washing. Rubber dried in the air, with no attention paid to light or temperature, was graded over 20% below rubber treated in every other respect the same, so far as our records could determine, but dried in the vacuum dryer at a temperature below 120° F. That this was due in large measure to the difference in temperature which was established by drying one sample in the vacuum dryer with the door left open, so that no vacuum was created. Under these conditions, the temperature alone was responsible for the noticeable increase in tensile strength and stretch which

took place during three hours. As the Station is not equipped with apparatus for making accurate strength tests, either absolute or comparative, only rather marked differences can be noted at the present time.

The practice during most of the 1912-13 crop on the plantations was to dry in the atmosphere for two weeks or more and then finish the process in the vacuum dryer. The manufacturer's tests on rubber cured in this way given below, show a fairly uniform product, graded by them at 5 to 10% below Ceylon Plantation.

Below are the results of the seven analyses made since the adoption of this method of drying:

Date.	Loss in Washing	Strength	Elasticity	Resin.
July 16, 1912....	½%	1710	15¼"	3.98%
July 16, 1912....	⅔%	1660	15 "	4 %
July 16, 1912....	1 %	1660	15 "	2.12%
July 19, 1912....	**	1640	14¾"	2.91
Oct. 23, 1912....	2½%	1620	13⅜	5.09
Mar. 13, 1913....	2½%	1720	13⅜	2.90
Mar. 13, 1913....	1⅓	1740	13⅜	3.27
AVERAGE	1.21%	1675	14¼	3.47%

** Very slight.

As the loss in washing and drying includes moixture as well as other foreign matter, it is plain that notwithstanding the large amount of dirt collected with the rubber, it is possible to remove this with the equipment now on the plantations.

It is probable that quite as good a product could be obtained with a properly equipped drying room, with artificial heat. The comparative economy of the drying room and vacuum dryer would constitute the determining factor in the final choice.

It is hoped that during the coming year the Substation may be equipped to make comparative strength tests at once, when it will be possible to determine the comparative value of the two methods of drying.

There is a possibility that the additional washing required to remove the large amount of dirt due to the method of collecting may weaken the rubber somewhat. At present we have not been able to determine this.

The rubber from which the analysis of October 23 was made was collected during the summer months, when the weather was warmer and dryer than during the winter. The high resin content of this sample lends color to the theory that the weather or climate has some effect on the quality in this respect.

We are indebted to The Manhattan Rubber Manufacturing

Company for the above analyses. In reporting on various samples tested by them they have remarked: "Nahiku Rubber is almost as good as Ceylon, except that there is some loss in washing." The above rubber compares favorably with Ceylon, being about 5 to 10% poorer in quality." "About 10% poorer than Ceylon, as loss in washing is about 2 1-5%" etc. With regard to the rubber cured in light, and in ordinary temperature, their comment was that it "could best be classed with guayule."

From this it may be concluded that, tapped and collected as above described, and dried in the vacuum dryer, our plantations can turn out a product about 5 to 10% below Ceylon plantation rubber in quality. Even if it were possible to make our Ceara rubber equal to the Ceylon Para, of which there is some doubt, by keeping the latex clean with the use of cups and spouts, the additional expense would more than offset the difference. It is possible also that with better facilities and greater experience we may be able to overcome some of the difference that now exists.

It was found that if the temperature of the heating water in the vacuum dryer is allowed to go above 120° F the rubber becomes soft and sticky in spots.

SUMMARY.

The general conclusions with regard to the plantations at Nahiku are:

a. That it is better to plant closely and later thin out to about 20 by 20 in the case of seedliings than to plant 20 by 20.

b. That propagation by selecting cuttings from the best yielding trees is the best means of extending the plantations.

c. The cheapest effective method of weed eradication is by the use of arsenite of soda, and indications are that aeration can be obtained without excessive erosion by using dynamite.

d. The best method of tapping so far is by removing the outer bark in narrow vertical strips and tapping these strips by incision, allowing the latex to coagulate on the ground.

e. Drying in the air at ordinary temperature has not given a uniformly good product, but a uniform product of high quality is obtained by drying for two weeks or more in the air at ordinary temperature and finishing in the vacuum dryer at artificial temperature not greater than 120° F.

f. The product of the Hawaiian plantations can be depended upon to bring a price within 5 to 10% of that of Ceylon plantation rubber.